A

Project Report
On

"Design and Fabrication of Low Cost Ventilator with Blood Sensing and Temperature Monitoring"

submitted to

Sant Gadge Baba Amravati University,
Amravati (M.S.) 444 602

in partial fulfillment of the requirement

for the degree of

BACHELOR OF ENGINEERING
in
MECHANICAL ENGINEERING

by

Abhishek Tiwari

Piyush Kolte

Meher Deshmukh

Akshay Kachole

Rohan Chaudhary

under the guidance of

Prof. S. Q. Syed

Department of Mechanical Engineering
Shri Sant Gajanan Maharaj College of Engineering
Shegaon-444203 (M.S.)
(Recognised by AICTE, accredited by NBA, New Delhi, NAAC, Banglore & ISO 9001:2000)
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Certificate

This is to certify that the project report entitled **"Design and Fabrication of Low Cost Ventilator with Blood Sensing and Temperature Monitoring"** is hereby approved as a creditable study carried out and presented by

Abhishek Tiwari	(PRN: 203120429)
Akshay Kachole	(PRN: 193120192)
Piyush Kolte	(PRN: 193120224)
Meher deshmukh	(PRN: 193120286)
Rohan Chaudhari	(PRN: 193120452)

in manner satisfactory to warrant of its acceptance as a pre-requisite in a partial fulfillment of the requirements for the degree of Bachelor of Engineering in Mechanical Engineering of Sant Gadge Baba Amravati University, Amravati during the **Session 2022-23.**

Prof. S.Q. Syed
Guide
Mechanical Engineering Department
SSGMCE, Shegaon.

Prof. C. V. Patil
Project Coordinator
Mechanical Engineering Department
SSGMCE, Shegaon.

Dr. S. P. Trikal
Professor and Head
Mechanical Engineering Department
SSGMCE, Shegaon

Dr. S. B. Somani
Principal
SSGMCE, Shegaon.

Acknowledgement

It is our utmost duty and desire to express gratitude to various people who have rendered valuable guidance during our project work. We would have never succeeded in completing our task without the cooperation, encouragement and help provided to us by then. There are a number of people who deserve recognition for their unwavering support and guidance throughout this report.

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– Projectees

Abhishek Tiwari

Piyush Kolte

Meher Deshmukh

Akshay Kachole

Rohan Chaudhary

ABSTRACT

This study presents the development of a low-cost, portable mechanical ventilator designed specifically for emergency situations, particularly in remote areas with limited resources. The device utilizes an automated AMBU resuscitator system actuated with a lead screw mechanism, providing precise control over ventilation parameters such as PEEP, peak pressure, tidal volume, I/E, and BPM while operating in pressure mode. The prototypes of the ventilator are lightweight, affordable, and pneumatically driven, allowing real-time operation based on the patient's oxygen saturation level. The safety of the device is ensured through the integration of airway oxygen sensors, valves, and other controllable safety attachments. The ventilator effectively delivers the required ventilation volume per breaths per minute, with realtime settings displayed on an LCD screen. The lead screw actuated BVM compression strategy demonstrates its efficacy as a low-cost, low-power ventilator technology that encompasses key ventilator features. Additionally, the device incorporates a pulse oximeter for monitoring oxygen saturation levels and stroke length to optimize performance. This portable mechanical ventilator aims to provide a cost-effective solution for emergency respiratory support, reducing the need for ICU occupancy and allowing for the care of patients with milder symptoms in a more accessible manner.

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CHAPTER 01

INTRODUCTION

Chapter 1

INTRODUCTION

Respiration is a fundamental physiological process for human survival. However, various factors such as disease, trauma, infections, neuromuscular disorders, etc. can impede the normal physiology, requiring external support to carry out this function. In such conditions, mechanical or assisted ventilation becomes crucial and can even be lifesaving. In India, an average of 20,000 patients suffering from head injuries, chronic respiratory ailments, anaphylaxis, and other injury-induced medical conditions require ventilatory support per day. Unfortunately, the scarcity of ventilators often forces caregivers to manually compress AMBU bags for prolonged hours, further highlighting the urgent need for more ventilators in the country. One of the most significant challenges in the fight against the COVID-19 disease, caused by the novel coronavirus SARS-CoV-2, is the potential global shortage of mechanical ventilators. Based on the projected number of patients who are expected to contract the disease in India and the percentage of these patients likely to require assisted ventilation, the demand for ventilators is expected to far exceed the current capacity. This demand is compounded by the fact that COVID-19 patients who develop acute respiratory distress syndrome (ARDS) often require prolonged periods of mechanical ventilation. As a result of the insufficient number of ventilators, physicians around the world are being forced to make difficult triage decisions regarding which patients to treat and which to let go. Increasing the number of ventilators is complicated by the complexity and cost of traditional ICU ventilators, which are further aggravated by the breakdown of regular supply chains as a result of the pandemic.

The primary objective of the automatic Ambu bag operating device for the low-cost ventilator design is to ensure safe and reliable production while meeting the specific requirements of COVID-19 patients with ARDS. This design approach focuses on reducing the part count, complexity, and cost of the device, as well as reducing or eliminating the reliance on scarce resources and parts. The design also prioritizes its ability to be implemented in different healthcare systems while ensuring that it has simple assembly, testing, and usage procedures that can be followed by healthcare personnel with limited experience in ventilation and no prior experience with this type of ventilator system.

In contrast to the modern ICU ventilators, which offer a wide range of ventilation modalities and intricate feedback loops for various respiratory parameters, the automatic Ambu bag operating device design emphasizes simplicity in its operation and assembly. Modern ICU ventilators require highly specialized staff for their operation, and regulatory requirements are understandably stringent. During the pandemic, emergency orders of ventilators from medical device manufacturers have been difficult to fulfill due to the breakdown of supply lines and the complexity of rapidly ramping up production of technically advanced ventilators. This shortage of ventilators is putting lives at risk, especially given the highly specialized medical requirements of COVID-19 patients with ARDS-like pneumonia.

We have designed a low-cost, easy-to-assemble, and portable automated AMBU resuscitator system with a proper air exhaust assembly to combat the ongoing pandemic. Our device provides precise control over various ventilation parameters, including peak pressure, tidal volume, and I/E, while operating in pressure mode. The system utilizes an AMBU resuscitator, which is pushed using 3D printed arms and driven by a lead screw mechanism powered by a single stepper motor. The entire device is assembled on an acrylic sheet, making it easy to lift and transport.

One distinctive feature that sets our project apart is the automation of compression settings in the ambu bag compression. Unlike other projects that rely on manual settings, our project implements automated compression, enhancing efficiency and accuracy. By automating the compression process, we reduce the likelihood of human error and ensure consistent and optimal compression levels. Additionally, our project incorporates data gathering capabilities. While other projects may focus solely on the mechanical aspects of the ambu bag, we have integrated sensors and data collection mechanisms to capture and analyze various parameters during compression. These parameters, such as pressure, frequency, and duration, are then uploaded to the cloud for further analysis and monitoring. By leveraging cloud technology, we enable real-time data visualization, remote monitoring, and comprehensive analytics. This not only enhances the performance but also allows healthcare professionals to track and assess the effectiveness of the compression over time. The data-driven insights derived from our project can contribute to improved patient care and better decision-making in emergency situations.

1.1 Principle Of Operation Of Mechanical Ventilator

A ventilator is a medical device that helps patients breathe by delivering a mix of air and oxygen into their lungs through a tube. This tube, also known as an endotracheal (ET) tube, is inserted into the patient's mouth or nose and down into their windpipe. This process is called intubation. In some cases, patients have a surgical hole in their neck through which a tube, called a tracheostomy or "trach" tube, is inserted into their windpipe. This is more secure than using an ET tube and can stay in place for a longer period of time. Patients with a trach tube can also use a speaking valve to communicate. The ventilator can fully take over a patient's breathing or just assist them in breathing. It blows a mixture of air and oxygen into the lungs, providing support to the patient's respiratory system.

A ventilator is a medical device that can provide higher levels of oxygen than other devices, such as masks. It achieves this by delivering a pressure, known as PEEP pressure, that helps keep the lungs open and prevents air sac collapse. Additionally, the tube in the windpipe can assist in the removal of mucus for patients with weak coughs.

It is important to note that the ventilator should cease delivering air as soon as the patient begins breathing on their own. Continued operation during active respiratory function may result in lung damage and vomiting. So, there is a system to monitor when the patient starts to breathe himself and stop the operation of the ventilator.

1.2 Operation Of Ambu Bag

Various parts of ambu bag can be identified through figure 1.1

Manual resuscitators, also known as bag-valve masks (BVMs), are used to provide artificial ventilation to patients. When compressed by the rescuer, the inflatable bag portion forces gas through a one-way valve and into the patient's trachea, bronchus, and lungs via a mask. The rescuer must maintain the appropriate tidal volume and respiratory rate based on the patient's condition. The typical tidal volume for adults is 500 to 800 mL of air, and the typical respiratory rate is 10 to 12 breaths per minute. For infants, the typical respiratory rate is 20 breaths per minute.

Professional rescuers are trained to ensure that the mask portion of the BVM is properly sealed around the patient's face to prevent air leaks and optimize ventilation. It is important to note that manual resuscitators should only be used by trained healthcare professionals, as improper use can cause harm to the patient.

Function of Ambu bag parts are as follows :

1. Self-Inflating Bag: The bag is made of flexible material, such as silicone or latex, and is used to provide ventilation to the patient. The bag is squeezed by the healthcare provider to deliver oxygen or air to the patient's lungs.

2. Mask: The mask is the part of the Ambu bag that is placed over the patient's face. It is made of soft, pliable material and has an airtight seal to prevent air leakage. The mask comes in different sizes to fit patients of different ages and sizes.

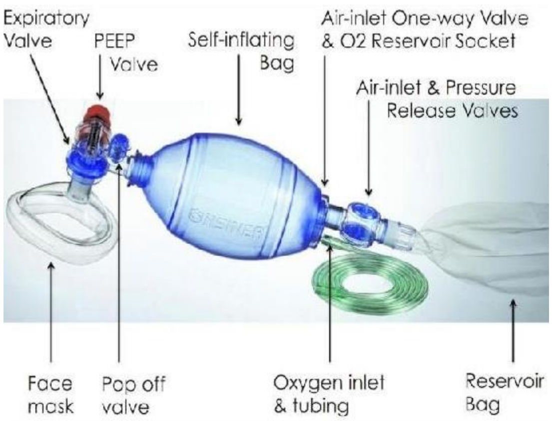

Fig 1.1 Different Parts Of Ambu Bag

3. Reservoir: The reservoir is a one-way valve that is located between the mask and the bag. It is used to prevent the patient from rebreathing exhaled air and to increase the concentration of oxygen in the inspired air.

4. Pressure relief valve: The pressure relief valve is a safety feature that is built into the Ambu bag. It is designed to prevent excessive pressure from being delivered to the patient's lungs, which could cause injury.

5. Oxygen inlet: The oxygen inlet is used to attach an oxygen source to the Ambu bag. Oxygen can be delivered through the bag to the patient to increase the concentration of oxygen in the inspired air.

6. Expiratory Valve: The expiratory valve regulates the flow of air or oxygen during exhalation, allowing for efficient removal of carbon dioxide from the lungs while preventing the re-inhalation of exhaled air.

7.PEEP Valve: Reduce delivered inspiratory pressure to an individual patient circuit, increase end-expiratory pressure for an individual patient circuit, and act as an one-way valve to ensure unidirectional gas flow through the divided circuit.

1.3 Aim & Objective

1.3.1 Aim

The development of low-cost mechanical ventilator aims is to mitigate the consequences of the shortages of ventilators in rural region for emergency purposes.

1.3.2 Objective

Our objective is to develop a portable and compact emergency ventilator that can be deployed in situations where traditional ventilators are unavailable. Other key objectives of our project are as follows:

➢ LOW COST: Modern ventilators used now days in hospital are too costly, starting price of these ventilators starts from 4-5 lakhs, so due to its heavy costing it cannot be available everywhere, so ours designed ventilator like model can be made available at portable cost.

➢ PORTABLE: To make portable design of ventilator, so that it can be carry easily whenever needed in emergency situations.

➢ USER FRIENDLY: Ventilators that which are been used in hospital, contain sophisticated control panel, due to that it is not easy to operate that ventilator at beginning stage by non-medical person. Our aim is design such ventilator so it can be operated easily by anyone without having prior experience.

➢ EASY TO ASSEMBLE: Any technician and non technician person can easily assemble and disassemble, all parts of ventilators when required.

CHAPTER 02

LITERATURE REVIEW

Chapter 2

LITERATURE REVIEW

2.1) Introduction

The title ‘Development of Low-Cost Ventilator’ requires an amount of good understanding on the knowledge of the science. Therefore, executing a research is necessary to obtain all the information available and related to the topic. The information or literature reviews obtained are essentially valuable to assist in the design, construction and specification of this final year project. With this ground established, the project can proceed with guidance and assertiveness in achieving the target mark.

2.2) Evaluated Paper

In the following literature review, here discuss pertinent information about the topics involved in our research, as well as recent, pertinent studies.

Leonardo Acho, Alessandro N. Vargas and Gisela Pujol-Vázquez., [1] Designed and construct a low-cost, open-source mechanical ventilator. The ventilator compresses ambu bag with actuator and its shaft to deliver breaths. They also shows a numerical method for monitoring the patients’ pulmonary condition. The method considers pressure measurements from the inspiratory limb and alerts clinicians in real-time whether the patient is under a healthy or unhealthy situation. Experiments carried out in the laboratory that had emulated healthy and unhealthy patients illustrate the potential benefits of the derived mechanical ventilator.

Sazzad Hossain Sazal, B. Tech. in ME (JNTU-A, India) M.Sc. Engg student & TA Dept. of Mechanical Engineering, KUET, Khulna -9300. [2] Designed and developed a low-cost portable ventilator that can help pneumonia cases of COVID-19 patient in Bangladesh. This low-cost ventilator delivers breaths by compressing a conventional Bag Valve Mask (BVM) or Ambu bag with a pivoting motor drive mechanism, eliminating the need for a human operator. Among other features, the machine had invasive and non-invasive feature, and supports 500- 600 mL tidal volume, with a continuous working capability for several days. Based on calculation, 12 Respiratory rate (RR)/min can provide required amount of tidal volume to the pneumonia patient.

Rajeev Chauhan, Raman Sharma, Nidhi Chauhan. [3] Designed a prototype of device was work on the principle of an electric linear actuator which converts the rotary motion into a linear motion. The designed device was connected to a regular adult AMBU. It has mechanism to rhythmically compress the AMBU. A direct current (DC) motor (12–24 V) was given the linear motion through electric linear actuator arrangement. In addition, this DC motor has speed regulator which is used to modulate the frequency of respiratory rate (varying from 12 to 20 squeezes per min) for supplying the air oxygen mixture into the lungs of the patient. There is a provision of the common platform so that the AMBU bag can squeeze automatically as per the regulated speed setting in the speed regulator of theDC motor.

Adamos Christou, Markellos Ntagios, Andrew Hart, and Ravinder Dahiya. [4] Design and implementation of one such emergency ventilator called GlasVent is presented, which an automated version of manual resuscitator device, commonly known as big valve mask or artificial manual breathing unit bag and widely used prior to initiating the mechanical ventilation. GlasVent uses 3D printed mechanical parts, widely available materials and off- the-shelf electronic and sensing devices which can be fast assembled. Furthermore, it requires minimal training and can be operated manually by hands or legs, thus meeting the emergency requirements even in the low-resource settings or regions with less developed healthcare systems.

Subha Hency Jose P, P. Rajalakshmy, P. Manimegalai, K. Rajasekaran, [5] Developed a prototype of device to assist patients who can partially breath by their own, they made it by using minimum number of components. They used needle valve with potentiometer to replace the flow analyzer and to make it cost effective.

Abdul Mohsen Al Husseini, Heon Ju Lee, Justin Negrete, Stephen Powelson, Amelia Servi, Alexander Slocum, Jussi Saukkonen, [6] Developed a Low-cost Portable Mechanical Ventilator and used cam type actuation mechanism to compress ambu bag , such that air can be supplied to patients lung.

Mohit Kumar, Ravinder Kumar, Vishal Kumar , Amanpreet Chander, [7] Designed a Low-cost Ambu-bag Based Ventilator for Covid-19 Pandemic. The Ventilator uses HEM Filter can used when fresh air is withdrawn from atmosphere , so Hem Filter remove the undesired contaminants present in the air. They used ultrasonic Sensors to detect position of arms which is used for pumping purpose, as when the ventilator starts, the arm positions are unknown to the machine ,before starting of whole mechanism ultrasonic sensor gives signal to microcontroller to check position to arms , if position is according to preset value(distance), then mechanism will start.

CHAPTER 03

FORMULATION OF WORK

Chapter 03

FORMULATION OF WORK

3.1 Problem Identification

After reviewing the published literature and drawing from clinical experience, we have identified several ventilation features that are crucial for the safe treatment of patients during this crisis. These features include utilizing a pressure control mode of ventilation, carefully monitoring the respiratory rate (RR), controlling the inspiratory time, and ensuring compatibility with external modular components such as adjustable positive end-expiratory pressure (PEEP) valves.

Our survey has revealed an urgent need for an automatic ambu bag operating device that can be rapidly deployed in emergency situations. This device should be designed to work with low cost ventilators, while providing the necessary functionality to effectively manage COVID-19 patients suffering from severe acute respiratory distress syndrome. As a result, we have chosen to focus on developing a low-cost ventilator for our project, which we have titled "Development of a Low-Cost Ventilator".

3.2 Research Methodology

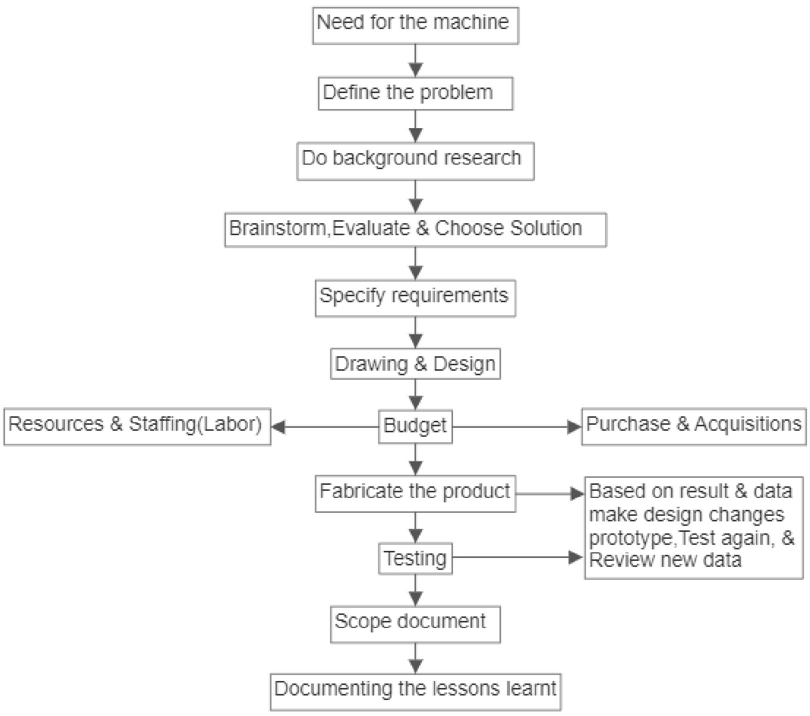

Fig. 3.1 Research Methodology

It involves the study of present design method. In this we will first identify the mechanical element to use to design and will find out dimension of machine component: .

a) Selection of compressing mechanism : For the compressing of ambu bag we select lead screw mechanism in which we compress the ambu bag from single side .

b) Selection of motor : Since our operation is light duty purpose and material is siliconwhich is difficult to compress, So, r.p.m of motor is not the matter but high torque is needed for compressing ambu bag for higher efficiency. We selected nema 12 stepper motor of torque 4.2kg cm at 12 volt .

CHAPTER 04

DESIGN OF MECHANISM

Chapter 04

DESIGN OF MECHANISM

4.1) Principle of Proposed Design

Where most emergency and portable ventilators are designed with all custom mechanical components, it was chosen to take an orthogonal approach by building on the inexpensive BVM, an existing technology which is the simplest embodiment of a volume displacement ventilator. Due to the simplicity of their design and their production in large volumes, BVMs are very inexpensive and are frequently used in hospitals and ambulances. They are also readily available in developing countries. Equipped with an air reservoir and a complete valve system, they inherently provide the basic needs required for a ventilator. The main drawback with BVMs (Ambu Bag) is their manual operation requiring continuous operator engagement to hold the mask on the patient and squeeze the bag. This operating procedure induces fatigue during long operations, and effectively limits the usefulness of these bags to temporary relief. Moreover, an untrained operator can easily damage a patient's lungs by over compression of the bag. The methodology taken has been, therefore, to design a mechanical device to actuate the ambu bag. This approach will result in an inexpensive machine providing the basic functionality required by mechanical ventilator standards.

4.2) Selection Of Mechanism

While selecting pumping mechanism for ambu bag we have consider number of factors such as :

- Portability of Mechanism
- Torque bearing capacity of the mechanism
- Price of the mechanism
- Easy replacement of parts of mechanism if required

So by considering all of the above factors we considered following mechanism for our project :

- Rack and Pinion Mechanism
- Both side push mechanism
- Leadscrew Mechanism

All Mechanism expect leadscrew mechanisms are facing some difficulties in terms of torque holding capacity of stepper motor, so at last we decided to use leadscrew mechanism.

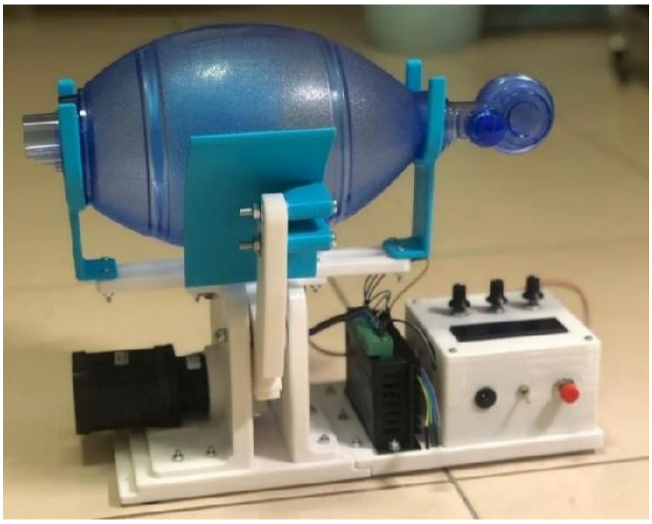

Fig. 4.1 Both side Push Mechanism

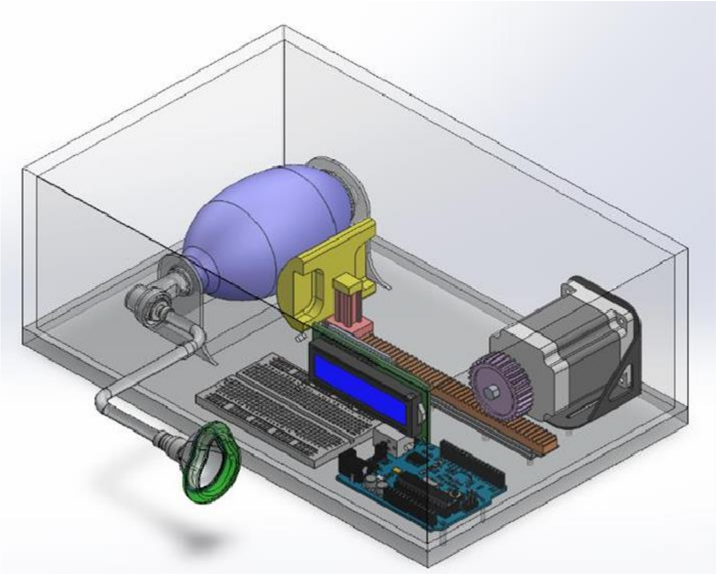

Fig. 4.2 Rack and Pinion Mechanism

4.3) Lead Screw Mechanism

CAD Model of Lead screw mechanism is as follows:

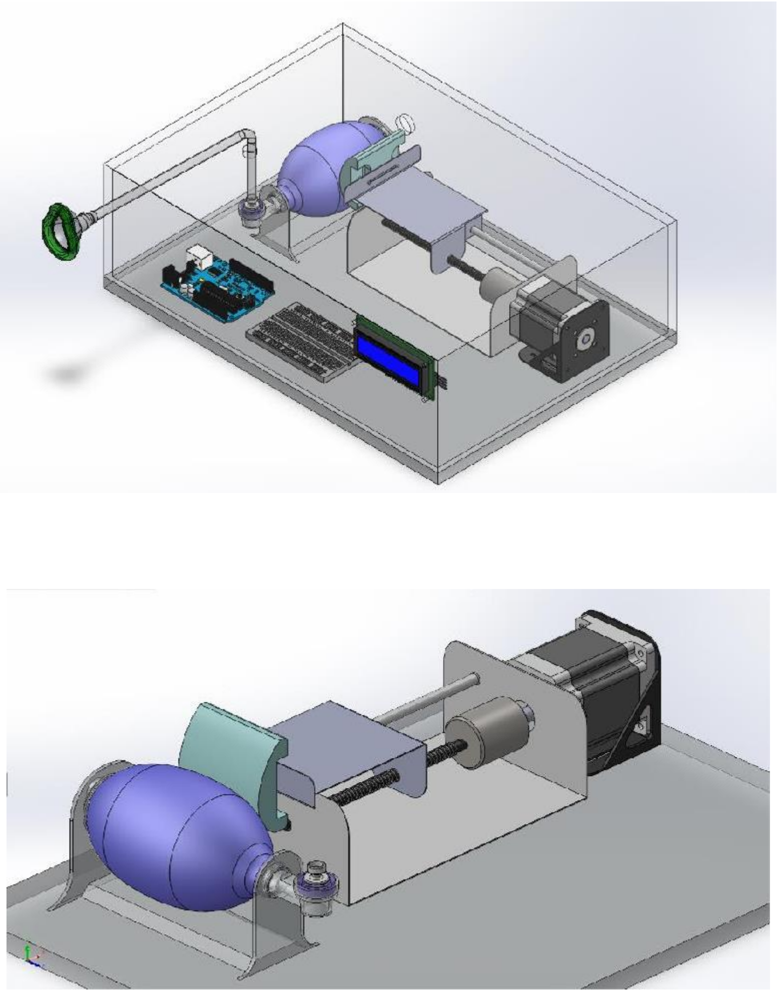

Fig. 4.3 Leadscrew mechanism

CHAPTER 5

DESCRIPTION OF COMPONENTS

Chapter : 5

DESCRIPTION OF COMPONENTS

5.1) Ambu Bag (Bag Valve Mask)

The bag valve mask (BVM), which is sometimes referred to as the Ambu bag or a manual resuscitator, is a portable device that is frequently used to provide positive pressure ventilation to patients who are not breathing or not breathing adequately. This device is an essential component of resuscitation kits used by trained professionals in out-of-hospital settings, such as ambulance crews. It is also commonly found in hospitals as part of the standard equipment on a crash cart, in emergency rooms, and other critical care settings. The American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiac Care highlight the significance and frequency of BVM usage in the United States and recommend that all healthcare providers should be familiar with its use.

It consists of a flexible bag made of silicone or other materials, which is connected to a mask that covers the person's nose and mouth. The bag has a one-way valve that allows air to be drawn into the bag when it is squeezed and then expelled into the person's lungs when it is released. The bag also has a pressure relief valve to prevent excessive pressure from being delivered to the person's lungs.

The device is operated by a healthcare professional who compresses the bag manually to deliver oxygen-rich air into the person's lungs. This can help to improve oxygenation and remove carbon dioxide from the person's body. Ambu bags are commonly used in emergency and critical care settings, such as during cardiopulmonary resuscitation (CPR) or when a patient is on a ventilator and needs to be temporarily disconnected for a procedure or transport.

5.2) Stepper Motor (Nema 17)

Fig. 5.1 NEMA 17 Stepper Motor

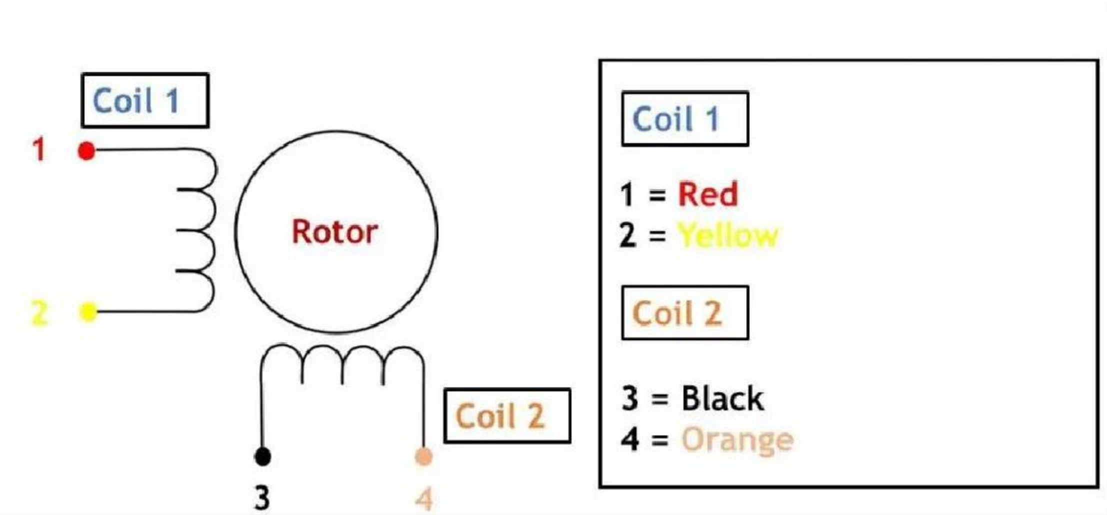

Fig. 5.2 Pinout Of 4 Wire NEMA 17 Stepper Motor

NEMA 17 is a type of stepper motor that is widely used in various applications, from 3D printers and CNC machines to robotics and automation systems. It gets its name from the National Electrical Manufacturers Association (NEMA), which sets the standard for motor dimensions in the US.They have a step angle of 1.8 degrees per step, which means they require 200 steps to make a full rotation (360 degrees).NEMA 17 motors are popular due to their compact size, high torque output, and versatility in various applications.

In our Project we have to precisely control the breath length and Number of strokes to Ambu Bag , so that purpose is fulfilled by stepper motor easily, that's why we have selected stepper motor over other motors.

Specifications and Features:

1. Step Angle: 1.8 Degrees

2. Holding Torque: 4.2 kg-cm

3. Operating Voltage: 12-24V

4. Supply Current : 1.7A/Phase

5. Shaft Diameter: 5mm

6. Weight : 288 gm

7. The input pulse decides the rotation angle of the motor.

8. High accuracy of around 3 to 5% a step.

9. It provides good starting, stopping, and reversing.

10. Control of this motor is less costly because of the exclusion of complex circuitry.

11.The speed is proportional to the frequency of the input pulses.

5.3)3d Printing Parts

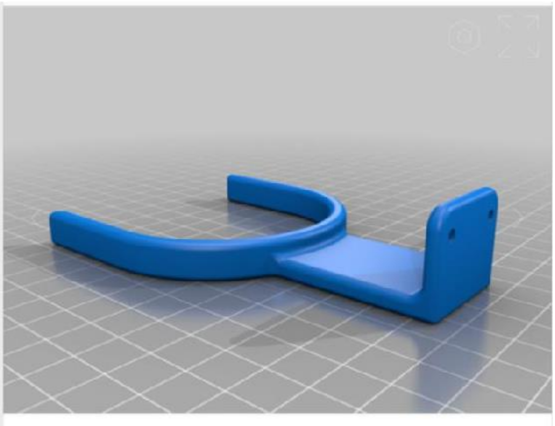

Fig. 5.3 Bigger Ambu Bag Holder

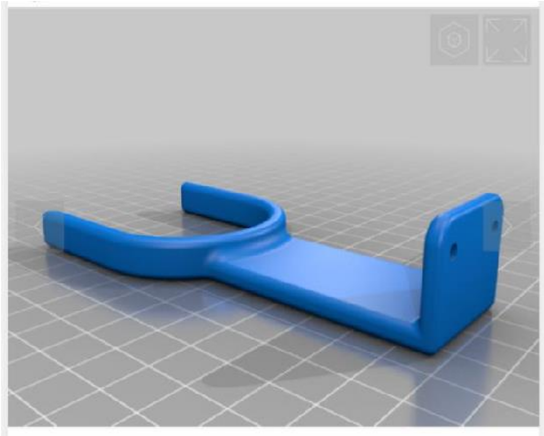

Fig. 5.4 Smaller Ambu Bag Holder

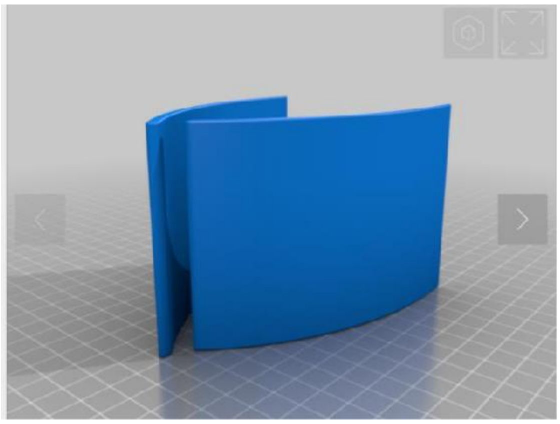

Fig. 5.5 Ambu Bag Pushing Part

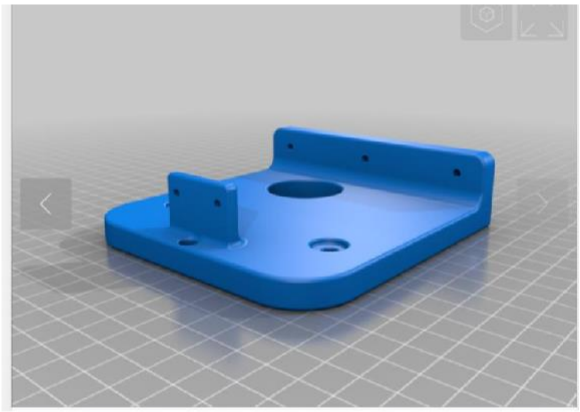

Fig. 5.6 Ambu Bag Support Part

3D printing is a process of creating three-dimensional objects from a digital file using a printer that builds the object layer by layer. This technology is also known as additive manufacturing, as it involves adding material layer by layer until the final object is complete.

The process of 3D printing starts with creating a digital model of the object you want to print using computer-aided design (CAD) software or by using a 3D scanner to create a digital copy of an existing object. The digital model is then loaded into the 3D printer, which uses a variety of materials such as plastics, metals, ceramics, and even living cells to build the object layer by layer. 3D printing is being used in a wide range of industries, including manufacturing, healthcare, education, and entertainment. It has many advantages, such as reducing the time and cost of prototyping, allowing for greater customization, and enabling the creation of complex geometries that would be difficult or impossible to produce using traditional manufacturing methods.

In Our Project we have used 3D Printing for making number of components such as Ambu bag Holder(Smaller, Bigger end), Ambu bag Pushing Part , Ambu bag support.The functions all the components are as follows:

1. Ambu Bag Holder (Bigger,Smaller End) : This part is used to hold ambu bag from bottom side , smaller end is the which on which outlet part of the ambu bag is resting , whereas on bigger end inlet part of ambu bag is resting.

2. Ambu Bag Support: This part is used to support ambu bag from opposite side from which pushing of ambu bag is done. This ensures that proper support should be given to ambu bag so that pressing of ambu bag should be appropriate

3. Ambu Bag Pushing Part: This part is used to push ambu bag when required. This part is attached to leadscrew through some arrangement.

5.4) Node MCU (ESP32)

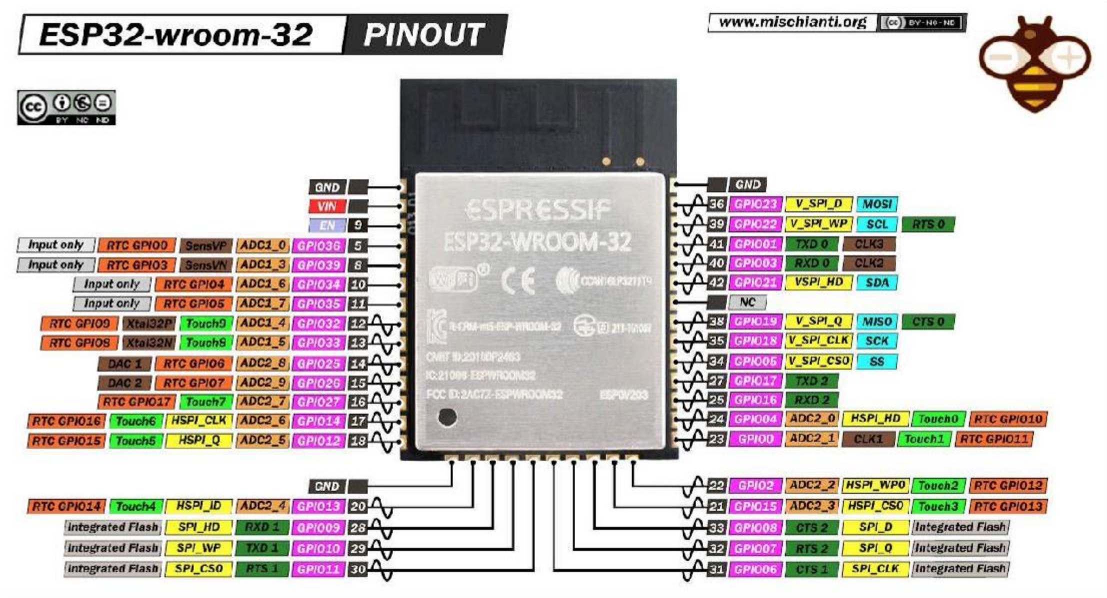

Fig. 5.7 Pinout For Node MCU

NodeMCU is an open-source development board that is based on the ESP8266 Wi-Fi chip. It comes with built-in Wi-Fi capabilities, mainly used for IOT purposes. The module integrates traditional Bluetooth, Bluetooth low energy and Wi-Fi. Wide range of uses: Wi-Fi supports a wide range of communication connections, as well as a direct connection to the Internet via a router; Bluetooth allows users to connect to a mobile phone or broadcast a BLE Beacon for signal detection. It connect sensors, actuators, and other devices to the internet and control them remotely. And also allows interaction with cloud services which makes it easier to collect and analyze data from your connected devices.

Features:

1.WIFI Frequency Range 2.4GHz ~ 2.5GHz

2.Clock frequency adjustment range from 80 MHz to 240 MHz, support for RTOS

3.Built-in 2-channel 12-bit high-precision ADC with up to 18 channels

4) Atmega 328p

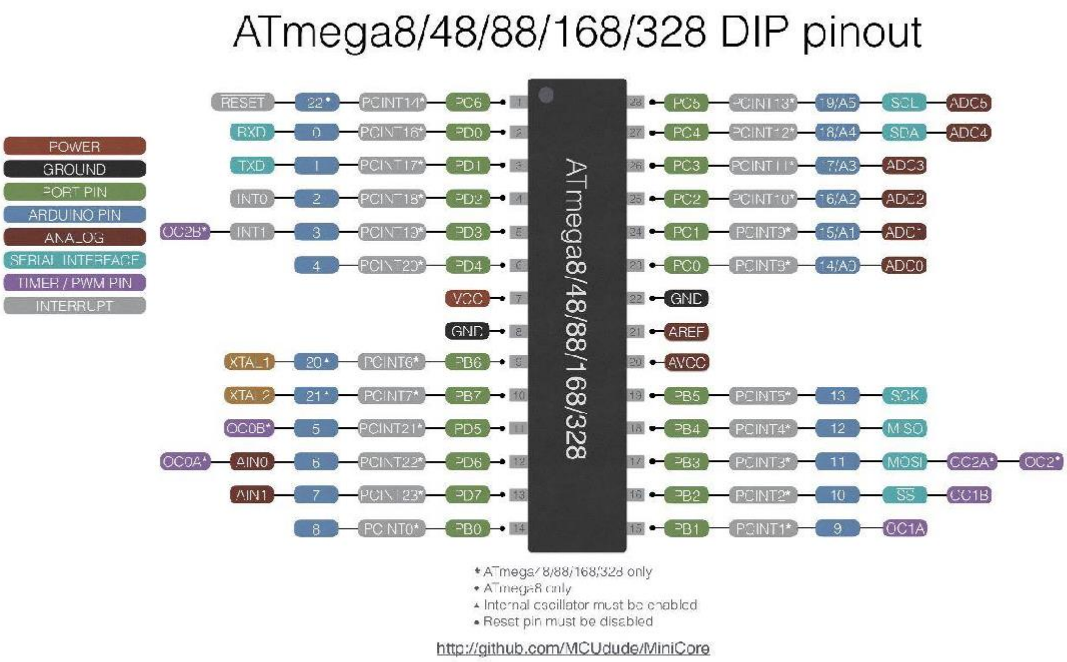

Fig. 5.8 ATmega328P is a Microcontroller Chip

ATmega328P is a microcontroller chip that is widely used in various electronic applications, especially in the field of embedded systems. It is a part of the AVR microcontroller.

The chip is designed to perform various functions and operations, and it is equipped with a wide range of features that make it suitable for various applications. It has 32KB of flash memory, 2KB of SRAM, and 1KB of EEPROM, which provides enough memory to store program code, data, and settings.

The microcontroller works by executing instructions that are stored in its flash memory. It is programmed using a programming language like C or Assembly, and the code is compiled and uploaded to the microcontroller using a programmer device. Once programmed, the ATmega328P chip can perform various functions, such as reading input signals, processing data, and controlling output devices, such as LEDs, motors, and sensors.

5.5)20*4 LCD Display

Fig. 5.9 20*4 LCD Display

This is a basic 20 character by 4 line display. Interface code is freely available. You will need 11 general I/O pins to interface to this LCD screen. Includes LED backlight. If you want to add some visual output to your Arduino projects, you'll need a display. If you need moderate data on display, the LCD2004 Parallel LCD Display is a quite good solution for Arduino projects. This is an industry-standard JHD629-204A based controlled 4 lines x 20 characters LCD display with Black characters on Blue background. It is a parallel interface so you will need 7 pins for 4-bit mode or 11 pins for 8-bit mode to interface to this LCD screen.

Features and Specifications:

1. Wide viewing angle and high contrast.

2. Supported 4 or 8-bit parallel interface. Operate with 5V DC.

3. Interface with 16 pins male header Connector.

4. 20 characters wide, 4 rows Black text on the green background. The module can easily interface with an MCU. The module is a low-power consumption character LCD Module with a built-in controller Single LED backlight included can be dimmed easily with a resistor or PWM.

5.Can be fully controlled with only 6 digital lines! (Any analog/digital pins can be Used

5.6) MAX30100 Pulse Oximeter Heart Rate Sensor Module

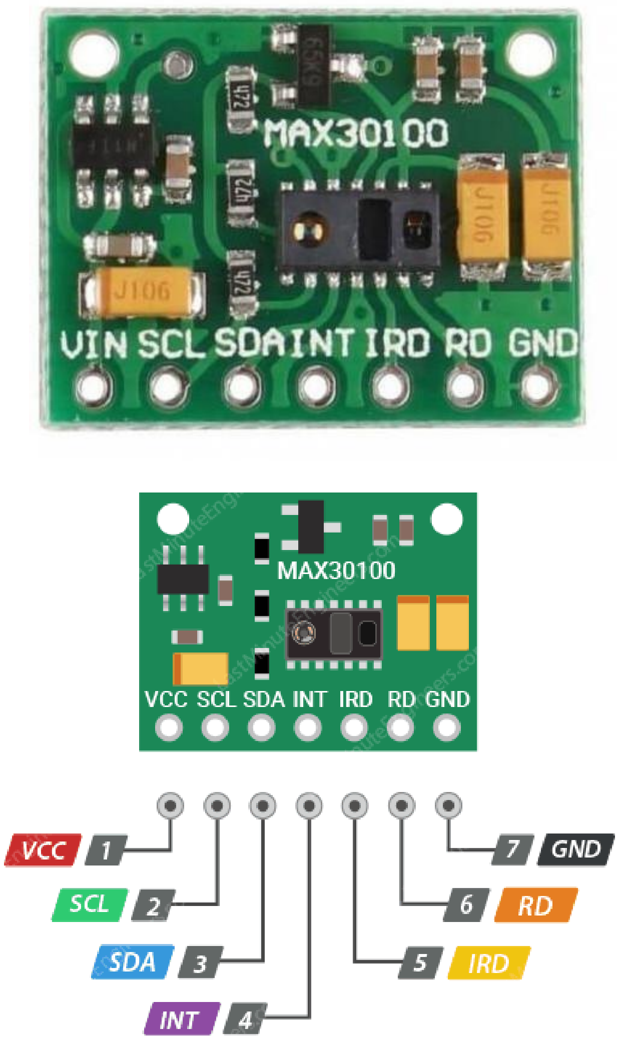

Fig. 5.10 MAX30100 Pulse Oximeter

The MAX30100 is a pulse oximeter and heart rate sensor module that uses optical sensors to measure blood oxygen saturation and heart rate. It is a low-power device that can be used in portable health and fitness applications, such as wearable fitness trackers and health monitoring devices.

The module uses two LED light sources, one emitting red light and the other emitting infrared light, to measure the absorption of light by blood vessels in the fingertip. The reflected light is then detected by a photodetector and analyzed by an onboard microcontroller to determine the oxygen saturation level and heart rate.It has a wide dynamic range, which means it can measure blood oxygen saturation levels accurately even in low-perfusion conditions. It also includes an integrated ambient light rejection algorithm, which helps to eliminate noise caused by external light sources and provide accurate measurements.

It can communicate with a microcontroller or a microcomputer through I2C or SPI interfaces. It is also compatible with Arduino boards, making it easy to integrate into various projects and applications.

Features and Specifications:

1. Optical sensor: IR and red LED combined with a photodetector.
2. 3.3V power supply complete pulse oximeter and heart rate sensor solution, simplifies design, integrated LEDs, photo sensor.
3. Ultra-low power operation increases battery life for wearable devices.
4. Ambient, light cancellation high sample rate capability fast data output capability.
5. It is an integrated pulse oximetry and heart rate monitor sensor solution.

5.7) HX710B Pressure Sensor

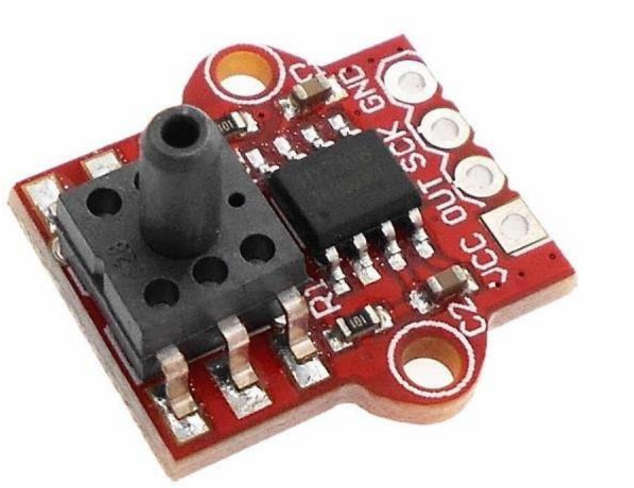

Fig. 5.11 HX710B Pressure Sensor

The HX710B is a type of pressure sensor manufactured by Hoperf Microelectronics Co., Ltd. It is a high-precision, low-power, and compact size sensor that is designed to measure the pressure of gases or liquids.

The HX710B pressure sensor can be used in a variety of applications such as automotive, medical, industrial, and consumer electronics. It is commonly used for measuring gas and liquid pressure in air conditioning systems, pneumatic controls, and hydraulic systems.

Features and Specifications:

1. Measurement Range: 0-40 kpa

2. Operating Voltage : 2.2-3.6 V

3. On-Chip Power Supply Regulator For Load Cell and ADC Analog Power Supply.

4. On-Chip Power-ON-Reset

5. Output: I2C or SPI digital signal

5.8) LM35 Temperature Sensor

Fig. 5.12 LM35 Temperature Sensor

The LM35 is a precision temperature sensor manufactured by Texas Instruments. It is a low-cost and easy-to-use sensor that can measure temperature with an accuracy of ±0.5°C over a range of -55°C to 150°C.The LM35 temperature sensor can be used in a variety of applications such as temperature control systems, environmental monitoring, and thermal protection. It is commonly used in HVAC systems, industrial automation, and consumer electronics.

The LM35 is available in a TO-92 package and can be easily interfaced with microcontrollers or other digital circuits. Its linear output makes it easy to use with analog-to-digital converters (ADCs) to read temperature values.

Specifications and Features:

1. Linear output: The LM35 provides a linear output voltage that is directly proportional to the Celsius temperature.

2. Low power consumption: The LM35 has a low quiescent current of 60 µA, making it ideal for battery-powered applications.

3. Wide range: The LM35 can measure temperatures from -55°C to 150°C.

4. Calibrated: The LM35 is pre-calibrated by the manufacturer, eliminating the need for additional calibration circuits.

5. 0.5°C Ensured Accuracy (at 25°C)

5.9) Stepper Motor Driver (A4988)

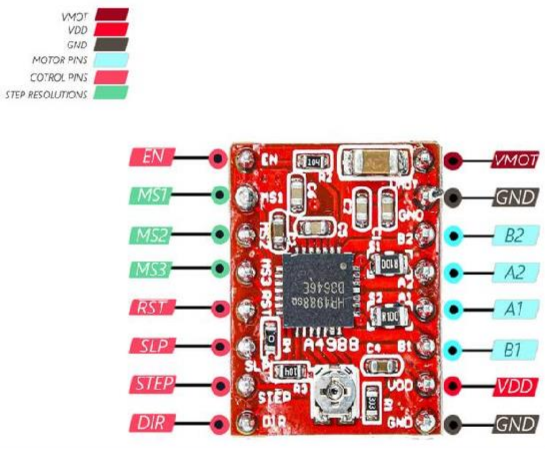

Fig. 5.13 Stepper Motor Driver (A4988)

5.10) SMPS 12 Volt , 2 Amp

Fig. 5.14 SMPS 12 Volt , 2 Amp

This industry power module converts AC power to 12V 2A DC. It has built-in over-voltage, over current, and short circuit protection. Perfectly designed and well constructed, small and compact Size with an indicator. A Switch-mode power supply is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. In our Project we requires 12v supply for operation of stepper motor.

Features and Specifications:

1. A High quality 12V 2A industrial power supply with an aluminum casing.

2. It works on input voltage range of 110-240VAC and input frequency range of 47~63Hz.

3. Design with built-in filter, improve signal precision.

5.11) Power Booster 12 Volt

A power booster 12 volt is typically an electronic device that increases the voltage of a 12-volt power source to a higher voltage level, usually to provide additional power to an electrical device or system that requires a higher voltage to operate.

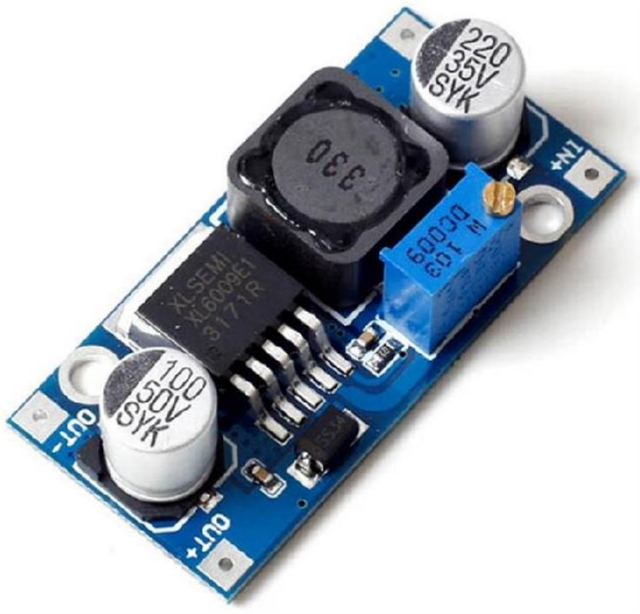

Fig. 5.15 Power Booster 12 Volt

Features and Specifications:

1. Wide input voltage 3V ~ 32V, optimum operating voltage range is 5 ~ 32V

2. Wide Output voltage 5V ~ 35V

3. High switching frequency 400KHz, can use a small-capacity filter capacitors that can achieve very good results, the ripple smaller and smaller.

5.12) Capacitors and Resisters

Today Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass. In analog filter networks, they smooth the output of power supplies. In our project we use three capacitors of capacity 1000μF,100 μF and 0.25 μF.

Fig. 5.16 100 μf Capacitor

Fig. 5.17 330 Ω Resistor

Capacitors perform following functions:

1. Charging and Discharging

2. Maintain the voltage at the same level.

3. Removing Noise.

Resistors are electronic components that are used to resist or limit the flow of electrical current in a circuit. They are passive components, which means that they do not require any power source to function. The resistance of a resistor is measured in ohms (Ω), and it determines how much current will flow through the resistor for a given voltage. Resistors are available in a range of values, from a few ohms to several megaohms. In our project we used two resistors of 330Ω, to limit voltage supply to LED.

5.13) Lead Screw And Coupling

Fig. 5.18 Lead Screw & Coupling

A lead screw is a mechanical component used to convert rotational motion into linear motion. It consists of a threaded rod (the screw) and a nut that fits over the screw and moves along its length as it rotates. The screw and nut are usually made of metal, and the thread is designed to provide a precise and stable motion. The performance of a leadscrew depends on several factors, including the pitch of the thread (the distance between adjacent threads), the diameter of the screw, and the material used for the screw and nut. One of the advantages of leadscrews is that they can provide a high mechanical advantage, which means that a small rotational force can be used to produce a large linear force. However, they also have some disadvantages, such as a limited maximum speed and the potential for wear and tear over time. In Our Project, we used 8mm diameter lead screw which is attached to the stepper motor through the coupler.

A 5mm to 8mm shaft coupler is a mechanical component used to connect two shafts with different diameters. It consists of a flexible coupling that can accommodate a 5mm shaft on one end and an 8mm shaft on the other end. When choosing a 5mm to 8mm shaft coupler, it is important to consider the torque and speed requirements of the application, as well as the compatibility of the coupler with the shafts and other components of the system. In Our Project, we used Coupler to join leadscrew and stepper motor shaft.

Specifications of Leadscrew and Coupling :

1. Pitch of lead screw : 2mm

2. Diameter of lead screw : 8mm

3. Material of lead screw : carbon steel

4. Material of coupling : aluminum

5.14) Jumper Wires

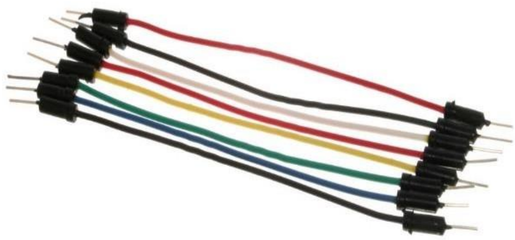

Fig. 5.19 Jumper Wires

A jumper wire (also known as jumper, jump wire, jumper cable, Dupont wire or cable) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply “tinned”), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

Individual jumper wires are fitted by inserting their “end connectors” into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

5.15) Lead Screw Hauling Plate

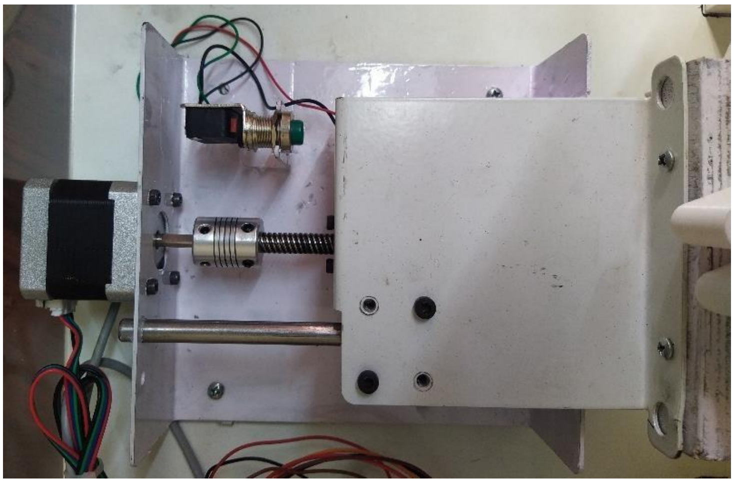

Fig. 5.20 Lead Screw Hauling Plate

To withstand the torque we have provided additional two plates plates which supports the leadscrew and ensure proper pumping of ambu bag , so that proper amount air should be provided to patients lung. We have provided plates from bottom and upper side. Plate is made up of Mild Steel.

5.16) 7805 IC

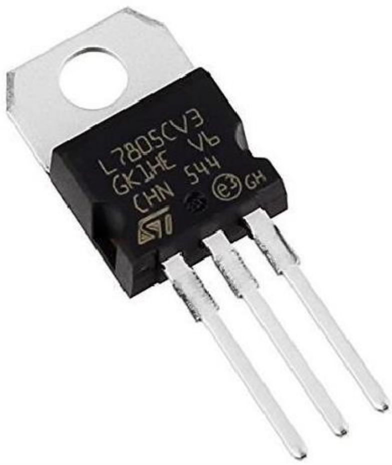

Fig. 5.21 7805 IC

The 7805 IC is a voltage regulator integrated circuit that is designed to provide a stable, regulated output voltage of 5 volts. It is a three-terminal linear regulator that can accept an input voltage ranging from 7V to 35V, and convert it to a stable 5V DC output.

5.17) Crystal Oscillator

Fig 5.22 16Mhz Crystal Oscillator

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a quartz crystal to create a stable and precise frequency. The quartz crystal vibrates at a specific frequency when an alternating current is applied to it, which makes it an ideal component for use in electronic oscillators.

Crystal oscillators are commonly used in electronic devices where precise and stable frequencies are required, such as in communication systems, digital clocks, and microprocessors. They offer a high level of frequency stability and accuracy compared to other types of oscillators, such as LC (inductor-capacitor) oscillators.

The frequency of a crystal oscillator is determined by the physical dimensions of the quartz crystal and the way in which it is cut and mounted. Crystal oscillators can generate frequencies ranging from a few kilohertz to hundreds of megahertz, and sometimes even into the gigahertz range.

5.18) HME+BV Filter

Fig 5.23 HME Filter

An HME (Heat Moisture Exchanger) is a medical device used in respiratory therapy for patients who require mechanical ventilation. It is designed to capture and retain heat and moisture from the patient's exhaled breath, and then release that heat and moisture to the patient's next inhalation. This helps to maintain optimal humidity levels in the patient's airway and reduce the risk of drying out the patient's airways during mechanical ventilation.

A BV (Bacterial/Viral) filter is a type of filter used in respiratory therapy to help prevent the spread of airborne pathogens. These filters are designed to capture bacteria, viruses, and other microorganisms that may be present in the patient's exhaled breath, and prevent them from being released into the surrounding air. This can help to reduce the risk of infection for healthcare workers and other patients who may be in close proximity to the patient receiving mechanical ventilation.

When used together, an HME and BV filter can help to optimize patient comfort and safety during mechanical ventilation. The HME helps to maintain optimal humidity levels in the patient's airway, while the BV filter helps to prevent the spread of airborne pathogens. This can help to improve patient outcomes and reduce the risk of complications associated with mechanical ventilation.

5.19) Switches

Fig 5.24 Feedback Switches

A push button is a type of switch that is activated by pushing a button or a lever. When the button is pressed, it makes a connection between two electrical contacts, allowing current to flow through the circuit. When the button is released, the connection is broken and current stops flowing.

There are two push buttons used. One button is used for feedback, which is used to provide input to the circuit based on the output of the circuit. The button could be used to toggle between different modes of operation based on the current state of the circuit.

The second button is used for switching and determining the travel distance and position. This button could be used to change the position or distance that the circuit controls. It is used to adjust the speed of a motor.

CHAPTER 6

CONSTRUCTION AND WORKING

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6.1) Working

The low-cost ventilator project is designed to provide respiratory support to patients with various respiratory illnesses. The device uses a stepper motor for actuation purposes and a lead mechanism to pump an Ambu bag. The project includes an oxygen sensor that measures the oxygen level of the patient, and the pumping frequency of the Ambu bag varies based on the patient's oxygen level.

The working of the ventilator is as follows:

- Oxygen sensor: The oxygen sensor is connected to the microcontroller, which measures the oxygen level of the patient in real-time.
- Microcontroller: The microcontroller processes the data from the oxygen sensor and determines the pumping frequency of the Ambu bag.
- Stepper motor: The stepper motor is connected to the microcontroller and is used to drive the lead mechanism that pumps the Ambu bag.
- Lead mechanism: The lead mechanism is designed to pump the Ambu bag by moving a lead screw. The stepper motor drives the lead screw to pump the Ambu bag.
- Ambu bag: The Ambu bag is a self-inflating bag used for manual resuscitation. The lead mechanism pumps the Ambu bag to provide respiratory support to the patient.
- Oxygen level control: The pumping frequency of the Ambu bag varies based on the patient's oxygen level. As the oxygen level drops, the pumping frequency of the Ambu bag increases, and as the oxygen level increases, the pumping frequency of the Ambu bag decreases.

In summary, the low-cost ventilator project uses a stepper motor to drive the lead mechanism that pumps the Ambu bag. The oxygen sensor measures the patient's oxygen level, and the microcontroller processes the data to determine the pumping frequency of the Ambu bag. The lead mechanism pumps the Ambu bag to provide respiratory support to the patient, and the pumping frequency varies based on the patient's oxygen level.

In our Proposed Solution, we are going to monitor Spo2 level in real-time and as Spo2 level drops below certain predetermined value the microcontroller senses this signal and thus give indication to Motor to increase its pumping Frequency.

Table 6.1 Variation Of Pumping Frequency As Per SPO2 Level

Sr No.	Spo2 Reading	Pumping Frequency
1.	95-100	10-12 Strokes/min
2.	90-95	12-15 Strokes/min
3.	90-85	15-20 Strokes/

6.2) Flow Diagram

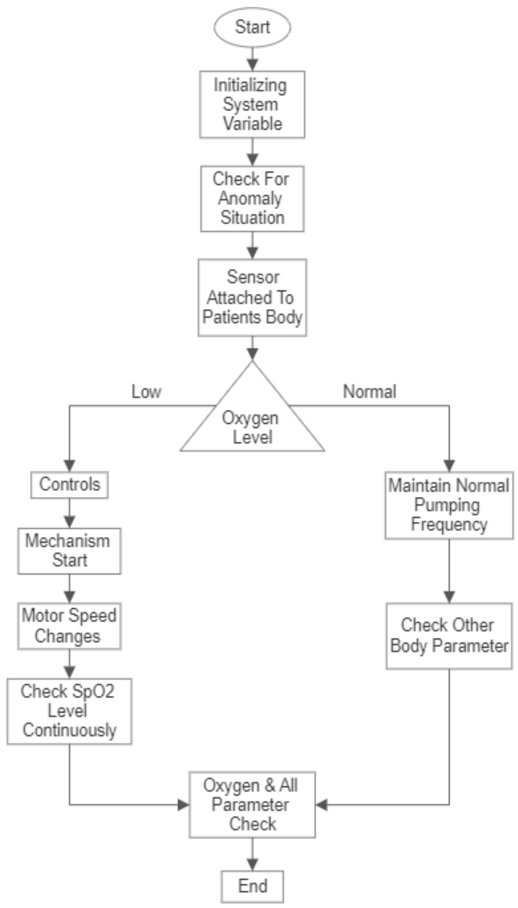

Fig 6.1 Flow Diagram

6.3) Block Diagram

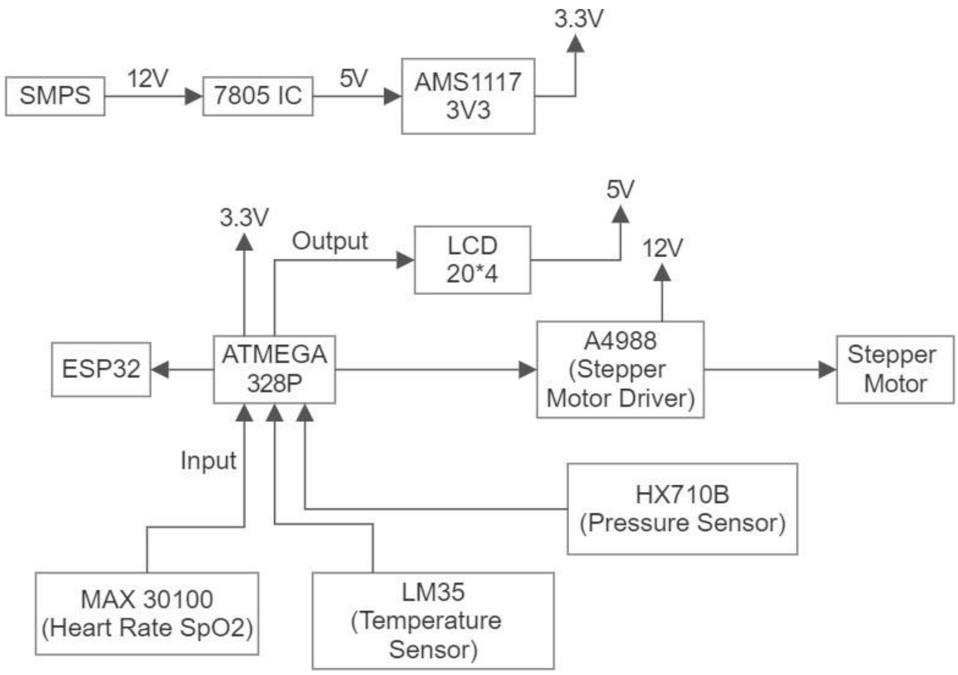

Fig 6.2 Block Diagram

6.4) Circuit Diagram

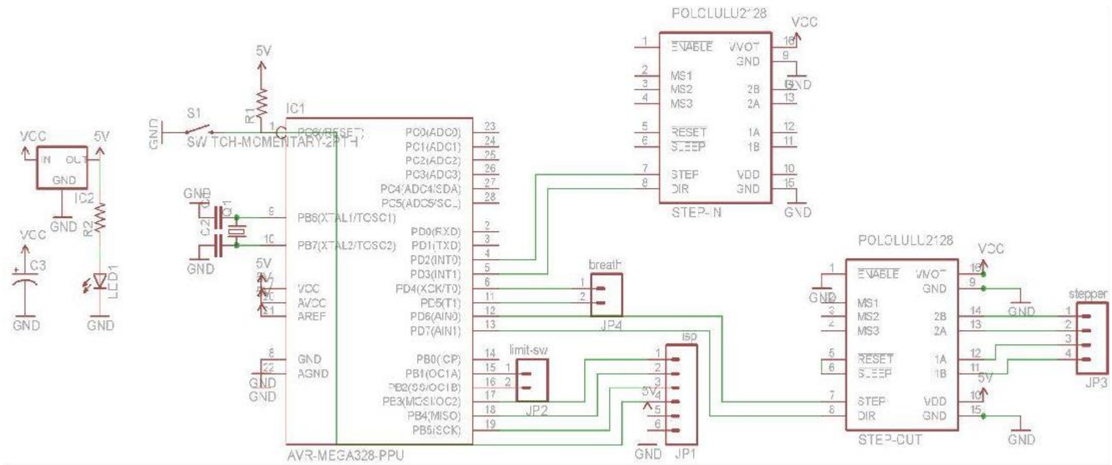

Fig 6.3 Stepper Motor Control Circuit Diagram

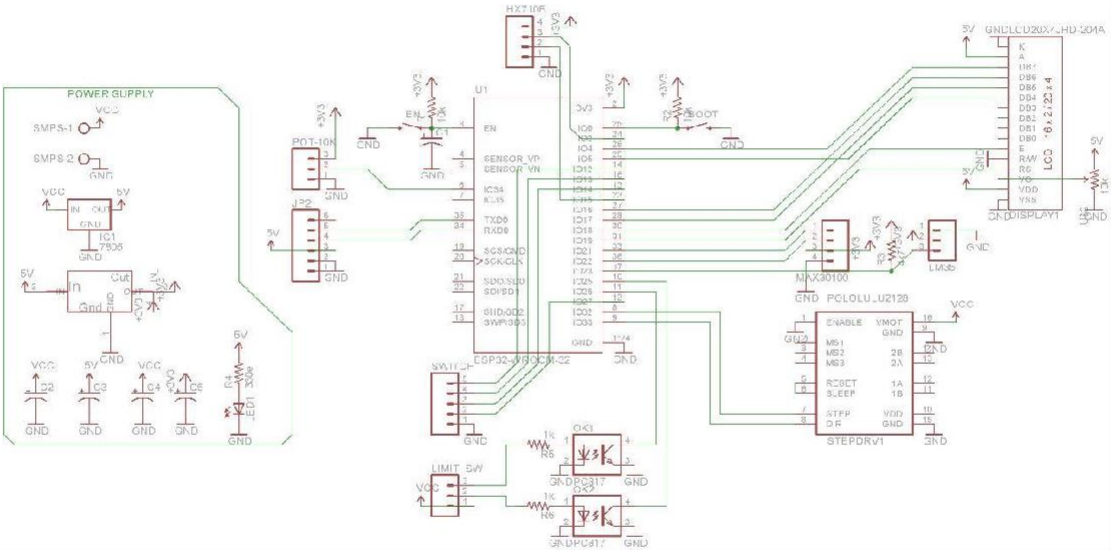

Fig. 6.4 Microcontroller Circuit Diagram

6.5) Code

```
#include <Wire.h>

#include <CircularBuffer.h>

#include <MAX30100.h>

#include <MAX30100_BeatDetector.h>

#include <MAX30100_Filters.h>

#include <MAX30100_PulseOximeter.h>

#include <MAX30100_Registers.h>

#include <MAX30100_SpO2Calculator.h>

#include "MAX30100_PulseOximeter.h"



#include <WiFi.h>

char ssid[] = "PROJECT"; // your network SSID (name)

char pass[] = "qwertyuiop"; // your network password

WiFiClient  client;
```

```
unsigned long myChannelNumber = 2033460;

const char * myWriteAPIKey = "FKJL7M9SKAEC72KP";

const char* host = "api.thingspeak.com";


#include <HX710B.h>

#include "HX710B.h"


const int DOUT = 2; //sensor data pin

const int SCLK  = 15;  //sensor clock pin


#include <LiquidCrystal.h>

const int rs = 19, en = 18, d4 = 5, d5 = 17, d6 = 16, d7 = 4;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);


#define pot_pin  34

#define ADC_VREF_mV    5000.0 // in millivolt

#define ADC_RESOLUTION 4096.0

#define PIN_LM35       39 // ESP32 pin GIOP39  connected to LM35


#define speed_delay  200


#define breath_up_sw    12
```

```
#define breath_dn_sw    13

#define blen_up_sw      14

#define blen_dn_sw      27

#define brlen_pin       32

#define bpm_pin         33


HX710B pressure_sensor;


#define REPORTING_PERIOD_MS     1000


// PulseOximeter is the higher level interface to the sensor

// it offers:

//  * beat detection reporting

//  * heart rate calculation

// * SpO2 (oxidation level) calculation

PulseOximeter pox;


unsigned long tsLastReport = 0;

unsigned long start_millis = 0;

unsigned long last_update = 0;


int adc;

int i = 0, z = 0, breath = 20, blen = 100;
```

```
float tempC, tempF, pressure_data;
int pulse = 0, oxygen = 0;


void init_max30100(void);
void setup() {
  // put your setup code here, to run once:
  Serial.begin(115200);
  lcd.begin(20, 4);
  lcd.clear();
  lcd.setCursor(4, 0);
  lcd.print("ROBOLTZ INC.");


  init_max30100();
  lcd.setCursor(0, 2);
  lcd.print("INIT MAX30100 SENSOR");


  pinMode(brlen_pin, OUTPUT);
  pinMode(bpm_pin, OUTPUT);
  digitalWrite(brlen_pin, LOW);
  digitalWrite(bpm_pin, LOW);


  pinMode(breath_up_sw, INPUT_PULLUP);
  pinMode(breath_dn_sw, INPUT_PULLUP);
```

```
pinMode(blen_up_sw, INPUT_PULLUP);
pinMode(blen_dn_sw, INPUT_PULLUP);

pressure_sensor.begin(DOUT, SCLK);
delay(2000);
lcd.setCursor(0, 3);
lcd.print("INIT PRESSURE SENSOR");
start_millis = millis();
tsLastReport = millis();
last_update = millis();

WiFi.mode(WIFI_STA);
delay(2000);
lcd.clear();
lcd.setCursor(4, 0);
lcd.print("ROBOLTZ INC.");
lcd.setCursor(0, 2);
lcd.print("SYSTEM INITIALISE DONE.");
delay(2000);
lcd.clear();
temperature_sensor();
read_pressure();
pox.begin();
```

```
  pox.setOnBeatDetectedCallback(onBeatDetected);
}

void loop() {

 pulse_oximeter();

  if (oxygen > 95)
  {
    breath = 10;
    digitalWrite(bpm_pin, LOW);
    blen = 50;
    digitalWrite(brlen_pin, HIGH);
  } else {
    if ((oxygen <= 95) && (oxygen > 90))
    {
      breath = 10;
      digitalWrite(bpm_pin, LOW);
      blen = 50;
      digitalWrite(brlen_pin, HIGH);
    } else {
      if ((oxygen <= 90) && (oxygen > 85))
      {
```

```
      blen = 100;

      digitalWrite(brlen_pin, LOW);

      breath = 20;

      digitalWrite(bpm_pin, HIGH);

    } else {

      if (oxygen <= 85)

      {

        blen = 50;

        digitalWrite(brlen_pin, HIGH);

        breath = 20;

        digitalWrite(bpm_pin, HIGH);

      }

    }

  }

}


if ((millis() - start_millis) > 60000)

{

  stopReadPOX();

  temperature_sensor();



  read_pressure();

  lcd.clear();
```

```
    lcd.setCursor(0, 1);

    lcd.print("UPLOADING DATA TO");

    lcd.setCursor(0, 2);

    lcd.print("THINGSPEAK IOT CLOUD");

    data_update();

    delay(2000);

    //startReadPOX();

    start_millis = millis();

    pox.begin();

    pox.setOnBeatDetectedCallback(onBeatDetected);

    lcd.clear();

  }

  lcd_display();


}



//=============FUNCTIONS================//



//=============MAX30100 Pulse Oximeter==========//

void onBeatDetected()

{

  delay(100);

  Serial.println("Beat!");
```

```
}

void init_max30100() {
  Serial.print("Initializing pulse oximeter..");

  if (!pox.begin()) {
    Serial.println("FAILED");
    for (;;);
  } else {
    Serial.println("SUCCESS");
  }
  // Register a callback for the beat detection
  pox.setOnBeatDetectedCallback(onBeatDetected);
}

void pulse_oximeter() {
  // Make sure to call update as fast as possible
  pox.update();

  Serial.print("Heart rate:");
  Serial.print(pox.getHeartRate());
  pulse = pox.getHeartRate();
```

```
  Serial.print("bpm / SpO2:");

  Serial.print(pox.getSpO2());

  oxygen = pox.getSpO2();

  Serial.println("%");

}


/*********** Function for pause MAX30100 Read *********************/

void stopReadPOX() {

  pox.shutdown();

}

/********* Function for Start MAX30100 Read *************/

void startReadPOX() {

  pox.resume();

}


//=============LM35====================//


void temperature_sensor()

{

  int adcVal = analogRead(PIN_LM35);

  // convert the ADC value to voltage in millivolt

  float milliVolt = adcVal * (ADC_VREF_mV / ADC_RESOLUTION);
```

```
  // convert the voltage to the temperature in °C
  tempC = milliVolt / 10;
  // convert the °C to °F
  tempF = tempC * 9 / 5 + 32;
}

//=======================Pressure Sensor HX710B===========//

void read_pressure() {
  if (pressure_sensor.is_ready()) {
    pressure_data = pressure_sensor.pascal();
    Serial.print("Pascal: ");
    Serial.println(pressure_data);
  } else {
    Serial.println("Pressure sensor not found.");
  }
}
//=================lcd display UI================//
void lcd_display() {
  lcd.setCursor(0, 0);
  lcd.print("O2=");
  lcd.print(oxygen);
  lcd.print(" %");
```

```
lcd.setCursor(10, 0);
lcd.print("HR=");
lcd.print(pulse);
lcd.print("bpm");
lcd.setCursor(0, 1);
lcd.print("AirPr=");
lcd.print(pressure_data);
lcd.print(" Pa");

lcd.setCursor(0, 2);
lcd.print("Temp=");
lcd.print(tempF);
lcd.print(" F");

lcd.setCursor(0, 3);
lcd.print("BPM=");
lcd.print(breath);

lcd.setCursor(10, 3);
lcd.print("BrLen=");
lcd.print(blen);
lcd.print("%");
```

```
  //delay(100);
}


//==========update IoT Server==================//
//=========data update to server using http====//


void data_update()
{
  if (WiFi.status() != WL_CONNECTED) {
    Serial.print("Attempting to connect to SSID: ");
    Serial.println(ssid);
    while (WiFi.status() != WL_CONNECTED) {
      WiFi.begin(ssid, pass); // Connect to WPA/WPA2 network. Change this line if
using open or WEP network
      Serial.print(".");
      delay(5000);
    }
    Serial.println("\nConnected.");
  }
  Serial.print("connecting to ");
  Serial.println(host);


  // Use WiFiClient class to create TCP connections
```

```
WiFiClient      client;
const int httpPort = 80;
if (!client.connect(host, httpPort)) {
  Serial.println("connection failed");
  return;
}

// We now create a URI for the request
String url = "https://api.thingspeak.com/update?api_key=FKJL7M9SKAEC72KP";
url += "&field1=";
url  +=  oxygen;
url += "&field2=";
url +=  pulse;
url += "&field3=";
url += pressure_data;
url += "&field4=";
url += tempF;

Serial.print("Requesting URL: ");
Serial.println(url);

// This will send the request to the server
client.print(String("GET ") + url + " HTTP/1.1\r\n" +
```

```
              "Host: " + host + "\r\n" +
              "Connection: close\r\n\r\n");
  unsigned long timeout = millis();
   while (client.available() == 0) {
    if (millis() - timeout > 5000) {
      Serial.println(">>> Client Timeout !");
      client.stop();
      return;
    }
  }

  // Read all the lines of the reply from server and print them to Serial
  while (client.available()) {
    String line = client.readStringUntil('\r');
    Serial.print(line);
  }
}

void switches()
{
  if (digitalRead(breath_up_sw) == LOW)
  {
    breath = 20;
```

```
    digitalWrite(bpm_pin, HIGH);
  }
  if (digitalRead(breath_dn_sw) == LOW)
  {
    breath = 10;
    digitalWrite(bpm_pin, LOW);
  }

  if (digitalRead(blen_up_sw) == LOW)
  {
    blen = 100;
    digitalWrite(brlen_pin, LOW);
  }
  if (digitalRead(blen_dn_sw) == LOW)
  {
    blen = 50;
    digitalWrite(brlen_pin, HIGH);
  }
}
```

6.6) IOT

IoT stands for "Internet of Things". It refers to the network of physical objects that are embedded with sensors, software, and connectivity, allowing them to collect and exchange data with other devices over the internet.

The concept of IoT is to connect various objects, machines, and devices to the internet, allowing them to communicate with each other and with humans, making them "smart" and enabling them to perform tasks that were previously impossible or required human intervention. The applications of IoT are diverse, ranging from smart homes, wearable devices, and industrial automation to smart cities, transportation, and healthcare. By enabling devices to communicate with each other and collect data, IoT has the potential to increase efficiency, reduce costs, and improve the quality of life for individuals and society as a whole.

We used IOT in our project to monitor health parameters of patients remotely, so that doctors can easily get information about patients health from wherever possible , by just having proper internet connection.

Health parameters that can be monitored are as follows:

- Oxygen level of Patient
- Heart rate of Patient
- Air Pressure at delivery side of ventilator
- Temperature of patients body.

Each of these health parameter value is going to update after 1min, after gathering wholesome of data , doctors can easily identify variation in patients health in day to day basis , and also doctors can identify any diseases in patient body based on these health parameters.

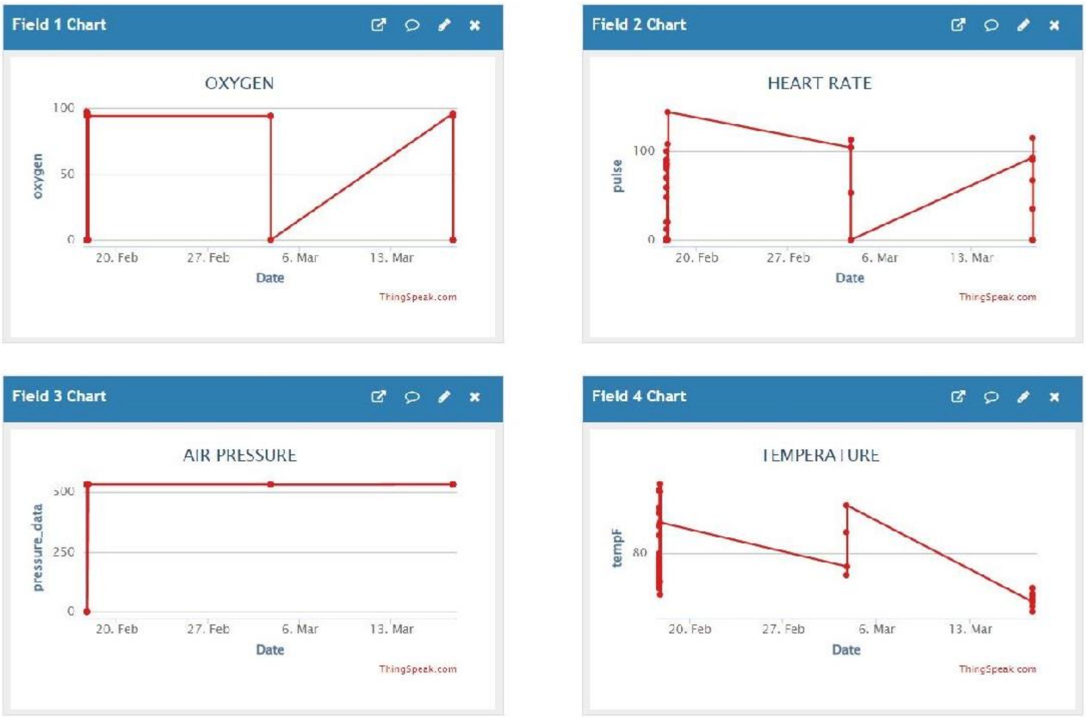

Fig 6.5 Data Monitoring Through IOT Webpage

CHAPTER 7

VENTILATION DYNAMICS

Chapter 7

VENTILATION DYNAMICS

1. Respiratory Rate (RR): Amount of breaths patient takes in 1 minute (Breaths per minutes).

2. Tidal Volume (VT): The amount of air that moves in or out of the lungs with each respiratory cycle. (mL or L)

3. Minute Ventilation (VE): Volume of gas inhaled or exhaled from a person's lungs per minute. (L/Min)

4. Flow Rate (V): The maximum flow at which a set tidal volume breath is delivered by the ventilator. Also known as speed of gas that patient inhales. (L/min, L/sec, mL/sec, mL/min)

5. Inspiratory Time (Ti): Amount of time that patient takes to inhale. (Seconds)

6. Expiratory Time (Te): Amount of time that patient takes to exhale. (Seconds)

7. Total Cycle Time (TCT): Beginning of inspiration to the end of exhalation.

8. IE Ratio (IE): The ratio of inspiratory time to expiratory time.

Age	Respiratory Rate	Inspiratory Time
Newborn	30 - 40 bpm	0.3 - 0.5
Infant (1 Year)	25 - 30 bpm	0.5 - 0.6
Child (1 - 5 years old)	20 - 25 bpm	0.6 - 0.8
Child (5 - 12 year old)	15 - 20 bpm	0.6 - 0.8
Adolescent/Adult	12 - 15 bpm	0.8 - 1.2

Fig 7.1 Respiratory Rate Chart For Various Age Group

7.1) Relationship between Minute Ventilation, Tidal Volume, Respiratory Rate

VE = Minute Ventilation

VT = Tidal Volume

RR = Respiratory Rate

For Example, VE = RR x VT

= 12/min x 200ml

VE = 2400ml or 2.4 Lit.

For Example, VT = VE/RR

= 10000ml or 10 Lit. / 10 min

VT = 1000ml or 1.0 Lit.

For Example, RR = VE/VT

= 10000ml or 10 Lit. / 500 ml

RR = 20/min.

7.2) Relationship between Respiratory Rate and Total Cycle Time

TCT = Total Cycle Time

RR = Respiratory Rate

For Example, TCT = 60sec / RR

= 60sec / 10

TCT = 6 sec

7.3) Relationship between Total Cycle Time, Inspiratory Time and Expiratory Time

TCT = Total Cycle Time

Ti = Inspiratory Time

Te = Expiratory Time

Ti = TCT – Te

Te = TCT – Ti

TCT = Ti + Te

For Example, If RR = 15/min	TCT = 60/15 = 4sec
Te = 3 sec	Ti = TCT – Te = 4 – 3
Ti = ?	Ti = 1 sec
For Example, If RR = 20/min	TCT = 60/20 = 3sec
Ti = 0.5 sec	Te = TCT – Ti = 3 – 0.5
Te = ?	Te = 2.5 sec
For Example, If Ti = 1.2 sec	TCT = Ti + Te
Te = 3 sec	= 1.2 + 3
TCT = ?	TCT = 4.2 sec

7.4) Relationship between Total Cycle Time, Inspiratory Time, Expiratory Time & I.E. Ratio

TCT = Total Cycle Time

Ti = Inspiratory Time

Te = Expiratory Time

I.E. Ratio = Compares Ti to Te

RR = 15/min TCT = 60/15 = 4 sec

Ti = 1 sec Te = TCT – Ti = 4-1 = 3 sec

I.E. Ratio = Ti/Ti : Te/Ti

= 1/1 : 3/1

= 1:3

7.5) Relationship between Flow Rate, Tidal Volume & Inspiratory Time

V = Flow Rate (unit – Lit./Min)

VT = Tidal Volume

Ti = Inspiratory Time

V = VT / Ti   VT = V x Ti   Ti = VT/V

For Example, VT = 0.5 L (Also express in ml)

Ti = 1 sec

V = VT/Ti = 0.5L/1sec

V = 0.5 L/sec

V = 0.5 L/sec x 60sec/1min

V = (0.5 L x 60) / 1 min

V = 30 L/min

V = 0.5 L/sec

Ti = 1 sec

VT = V x Ti

VT = 0.5 x 1

VT = 0.5 L or 500 ml

7.6) Calculations

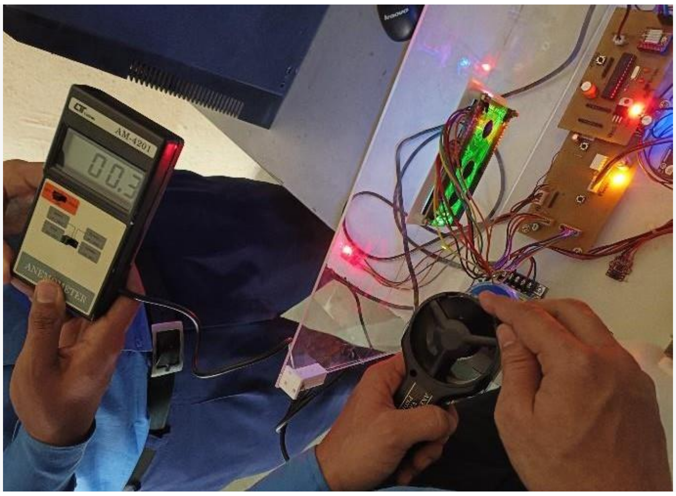

Fig. 7.2 Measuring Discharge using Anemometer

I. Flow Rate :- 0.3 to 0.4 m/s (90 – 95) oxygen flow

II. Flow Rate :- 0.2 m/s (95 – 100) oxygen level

$0.4 \times 60 = 24 m/min$ ……..(V_1) (I)

$0.2 \times 60 = 12 m/min$ ……..(V_2) (II)

do = outer diameter = 22mm

di = inner diameter = 15mm

Ambu Bag Diameter = 115.5mm

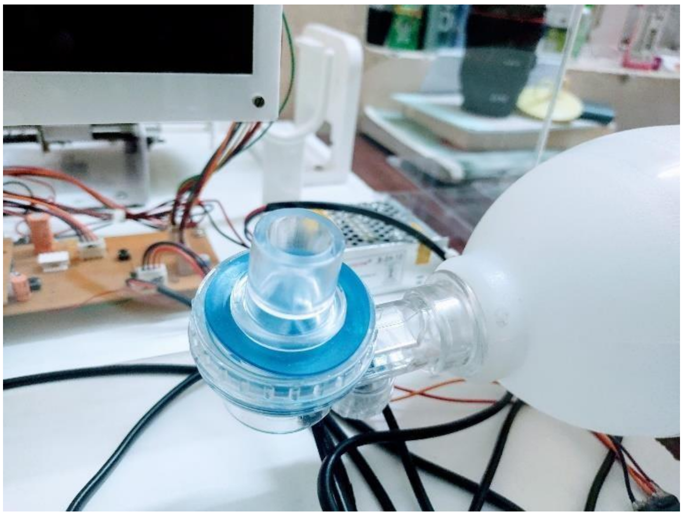

Fig 7.3 Outlet Of Ambu Bag

Ao = $\frac{\pi}{4} \times do^2 = \frac{\pi}{4} \times (0.022)^2$ (Ao = Outer Diameter of ambu bag outlet pipe)

Ao = $3.801 \times 10^{-4}\ m^2$

Ai = $\frac{\pi}{4} \times di^2 = \frac{\pi}{4} \times (0.015)^2$ (Ai = Inner Diameter of Ambu bag outlet pipe)

Ai = $1.767 \times 10^{-4}\ m^2$

Discharge / Tidal Volume

= Ao × V_1...From Eqn (I)

= $3.801 \times 10^{-4} \times 24$

= $9.124 \times 10^{-3}\ \frac{m^3}{min}$

= Ai × V_1

= $1.767 \times 10^{-4} \times 24$

= $4.248 \times 10^{-3}\ \frac{m^3}{min}$

= $0.00428\ \frac{m^3}{min}$

= $4280000\ \frac{m^3}{min}$

= 4.28 lit/ min

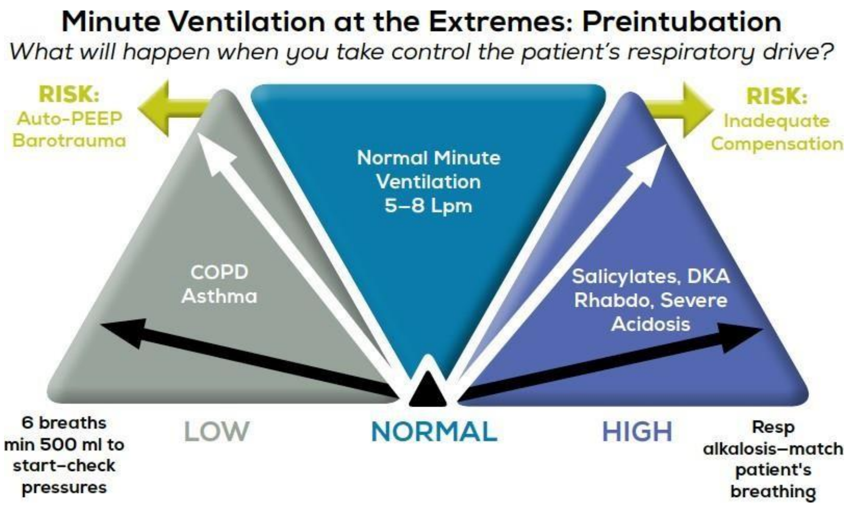

Fig. 7.4 Values of Minute Ventilation Allowed

Tidal Volume:-

Tidal Volume = $\frac{Minute\ Ventilation}{RR}$ [Respiratory Rate(RR) for mechanism is 12 strokes/min]

$= \frac{4.28}{12}$

= 0.356 lit

Tidal Volume = 356 ml

For 5 foot 9 inch = 70.7 IBW

Tidal Volume range = 420 – 570

% Comparison Accuracy = $\frac{356}{420}$

= 0.8476 *100

= 84.76 %

Target Tidal Volume:

Tidal volume is the measure of the amount of air inhaled during a normal breath. Safe tidalvolumes can be determined based on patient's height and gender and the rule of thumb, when lung-protective ventilation is required, is setting the tidal volume at 6-8 mL/kg ideal body weight.

Target tidal volume ranges from 6 to 8 mL/kg IBW, where:

IBW male = 50kg + 2.3 x (Height in inches – 60)

IBW female = 45.5kg + 2.3 x (Height in inches – 60)

- Traditional pre-set tidal volumes higher than 10 ml/kg have been proved to be associated with increased risk of pulmonary barotrauma, decreased venous returnand reduced cardiac output.
- In patients with acute lung disease, recent studies have shown correlation betweenuse of lower tidal volume and decreased mortality.

- Tidal volumes between 6 and 6 mL/kg IBW are advised in ventilating patients with acutelung disease such as:
    - Pneumonia;
    - Acute respiratory distress syndrome (ARDS);
    - Chronic obstructive pulmonary disease (COPD).

These calculations are helpful to compare the mass flow rate of air generated by our ventilator with standard data. By involving doctors in the certification process, we ensure that our ventilator meets the required standards and accurately delivers the necessary mass flow rate of air to effectively support patients' respiratory needs.

Through careful analysis and scientific validation, we establish the correlation between the ventilator's settings and the resulting mass flow rate. This involves studying parameters such as tidal volume, inspiratory time, respiratory rate, and peak inspiratory pressure. By understanding the relationships between these parameters and the delivered mass flow rate, we can fine-tune our ventilator's settings to align with the established standards. The involvement of certified doctors in this process ensures the accuracy and reliability of our calculations. Their expertise and understanding of respiratory physiology enable us to validate our ventilator's performance and make any necessary adjustments to optimize its functionality. This collaboration between engineering and medical professionals guarantees that our ventilator provides the required mass flow rate of air, meeting the critical respiratory needs of patients in emergency situations.

CHAPTER 8

COST ESTIMATION

Chapter 8

COST ESTIMATION

Table 8.1 Cost Estimation

Sr No.	Name Of Component	Specification	Quantity	Cost
1.	Ambu Bag with Mask and Piping	Silicon Resuscitator, Adult 1600 ml	1	1000
2.	Microcontroller	Atmega328p	1	475
3.	NodeMcu	ESP32	1	380
4.	LCD Display	20x4 LCD Display	1	600
5.	Pulse Oximeter & Heart Rate Sensor	Max30100 Module	1	128
6.	Stepper Motor	Nema-17	1	649
7.	Stepper Motor Driver	A4988	1	171
8.	Pressure Sensor	HX710B	1	167
9.	Temperature Measurement Sensor	LM35	1	12
10.	Air Filter	HME Filter	1	212
11.	3D Printed Parts		8	1750
12.	SMPS	12V, 2A	1	250
13.	Power Booster	12V (XL6009 DC to DC)	1	175
14.	Crystal Oscillator	16Mhz	1	8
15.	Capacitors	(1000µf, 100µf, 0.25 µf)		(63,40,10)

16.	Resistors	330Ω	2	10
17.	Switches	Feedback Switches	2	120
18.	Leadscrew	180mm long	1	300
19.	Coupling	5mm to 8mm	1	100
20.	Leadscrew Supporting Plates		2	300
21.	Jumper Wires	(M-M,M-F,F-F)	100	200
22.	Wires And Cables			100
23.	Soldering Lead		40gm	60
24.	Nut & Screw			100
25.	Plywood			100
26.	Acrylic Sheets with laser Cutting			1000
Total				8530

CHAPTER 9

FUTURE SCOPE AND APPLICATION

Chapter 9

FUTURE SCOPE AND APPLICATION

The low cost ventilator project has immense future scope for further development and improvements. In the future, the ventilator can be equipped with a battery backup system, making it independent of a power source, and ensuring uninterrupted ventilation for critically ill patients. This would be especially useful in situations where the power supply is cut off.

Furthermore, additional manual settings can be added along with the automatic ambu bag ventilation technique to provide a backup in case of a malfunction in the automatic features , This will make the ventilator more reliable and to use in emergency situations.

Another area for future development is the addition of oxygen concentrator to the ventilator system. This will helpful for patients who require oxygen therapy. It will make the ventilator more versatile and efficient in its functioning.

Finally, the design of the ventilator can be made more compact and portable for easy carrying purposes. This will make it easier for healthcare workers to transport the ventilator to remote locations or in emergency situations.

Overall, the low cost ventilator project has immense potential for further development and improvements in the future, which will make it more efficient, reliable , and useful for healthcare workers and patients.

CHAPTER 10

CONCLUSION

Chapter 10

CONCLUSION

In conclusion, we have successfully developed a prototype model of an Ambu bag-based low cost ventilator, which meets our objectives of being affortable and easy to operate. Through our calculations, we found that the ventilator can deliver a discharge of 356 ml per minute, which is sufficient for normal breathing.

During our visits to hospitals ,we received feedback from doctors that the pressure required for ventilation is a critical parameter , & we need to work on increasing the pressure intensity during ventilation. This feedback will be taken into account in our future development and improvements to ensure that the needs of healthcare workers and patient’s .

Our developed prototype has additional features such as the measurement of blood oxygen levels, heart rate, body temperature, and remote monitoring of all health parameters using IOT platform of Thinkspeak. These features will make the ventilator more useful and efficient in its functioning.

In summary, we are proud of progress we have made in developing a low cost ventilator prototype that has the potential to help people in need . We will continue to work on improving our design to meet the ever-changing needs of the healthcare industry and make our device more efficient and accessible to all.

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